SHIFT Safety Component Summary

Introduction

The Safety Team was tasked with evaluating the 2018 SHIFT safety components and suggesting improvements to the ranking methodology that reflect the most current and nationally accepted data-driven methods to evaluate safety. In doing such, the team used the Highway Safety Manual (HSM) as a guide to both evaluate the 2018 SHIFT safety component, and to develop a new method of evaluating safety for the 2020 SHIFT cycle.

Analysis of 2018 SHIFT Safety Component

Previously, the safety component was calculated using a combination of three safety measures; critical rate factor (CRF), crash frequency (CF), and crash density over a segment length (CD*L).

CRF is a measure that compares a segments crash rate to a crash rate that is considered critical, or much greater than the average crash rate for a segment of that roadway type. However, recent research has shown that CRF is not the most accurate or reliable method to compare a segment's crash performance to segments of a similar type. CRF relies on the assumption that crashes and traffic volume have a linear relationship, which is not always true. Regression to the mean bias is not addressed with CRF either, meaning CRF does not account for temporal fluctuation in crashes.

CF is simply the total number of crashes a location experiences in five years. This measure does not account for regression to the mean either. It also produces a length bias because longer segments will have more space available to accumulate crashes.

CD*L is an attempt to distinguish each SHIFT project based on its roadway type. The average crash density (crashes per mile) for each roadway type (interstate, parkway, urban multilane, rural two lane, etc.) was calculated. For each SHIFT project, the average crash density for that project's roadway type was multiplied by the length of the project to achieve the CD*L measure. This measure is supposed to represent the average number of crashes that could be expected on a roadway of the same type and length of the SHIFT project. This factor also creates a length bias, as longer SHIFT projects will have a higher CD*L score. This measure does not accurately reflect the number of crashes that should be expected on a roadway because factors other than roadway type and length influence crash occurrence, such as roadway geometry and traffic volume.

The three components for each project were scaled from 0-100 based on how their magnitudes ranked in comparison to all other SHIFT projects. The scaled values of the three components were combined for each SHIFT project to create a single safety score. The scaled components were weighted differently based on the length of a project. If the project was less than or equal to 0.2 miles, the project was considered an intersection. If the project was greater than 0.2 miles in length, the project was considered a segment. The following equations show how the three components were weighted to create a combined safety score for segments and intersections:

Segment (L>0.2): = $0.25*((CD*L)_{\dagger scaled}) + 0.25*(CRF_{\dagger scaled}) + 0.50*(CF_{\dagger scaled})$
Intersection (L<=0.2): = $0.5*(CF_{\dagger scaled}) + 0.5*(CRF_{\dagger scaled})$

The weighting of each of the three components shown in the equations above is arbitrary and also contributes to a length bias. In both the segment and intersection equations, CF contributes 50% of a projects score. As discussed, CF is influence by the length of a project, and longer projects tend to have higher crash totals.

2020 SHIFT Safety Component

The HSM promotes the use of safety performance functions (SPFs) to model crash frequency based on traffic volume and length of homogeneous roadway segments. SPFs are typically modeled using negative binomial regression, which is a more accurate representation of the relationship between crashes and traffic volumes than the assumed linear relationship with CRF. The estimated number of crashes calculated by an SPF represents the number of crashes one might expect on an average length of road with a given traffic volume. The functional form of an SPF is as follows:

$$\boldsymbol{SPF\ Crashes = L * e^{a} * AADT^{b} * AF}$$

Where,
SPF Crashes = crash prediction
L = Length of segment
AADT = annual average daily traffic
a & b = regression coefficients
AF = adjustment factor (if needed)

If a road segment does not identically match the base conditions of the homogenous roadway segments used to calibrate the SPF, then an adjustment factor (AF) must be applied to the SPF's crash prediction to account for the difference in roadway characteristics. For example, an SPF was developed from a dataset of rural two-lane roads that all had nine-foot lanes and three-foot shoulders. However, the SPF is used to predict crashes on a rural two-lane road with nine-foot lanes and two-foot shoulders. To account for the decrease in safety associated with reducing shoulder width by one foot, the SPF should be multiplied by an appropriate AF that reflects the increase in crashes that would be expected.

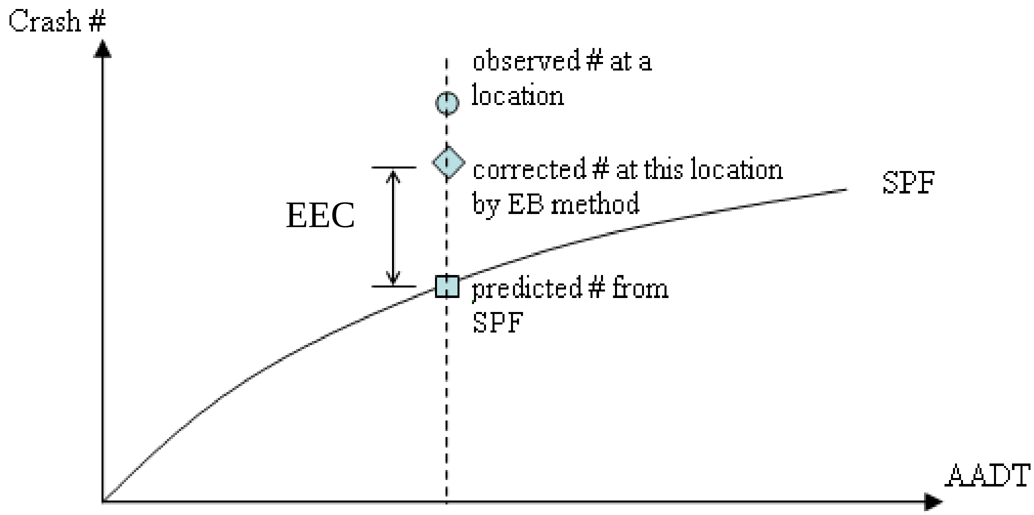
Furthermore, the HSM recommends the use of the empirical Bayes (EB) method, which combats regression to the mean by combining the SPF crash prediction for a segment with the historical crash data of that segment. The two crash measures are balanced using a weight parameter that is a function of how well the SPF model represents the dataset from which it was correlated. If the SPF has poor correlation, the weight parameter places more emphasis on the historic crash data, and vice versa. The EB method uses the following formula:

$$\boldsymbol{EB\ Expected\ Crashes = w * SPF\ Crashes\ + (1 - w) * Historic\ Crashes}$$

Where,

w = weight (based on overdispersion parameter from calibrated SPF)
SPF Crashes = predicted crashes on a segment from SPF
Historic Crashes = total historic crashes on a segment

The difference between EB expected crashes and SPF predicted crashes is a measure known as excess expected crashes (EEC). EEC quantifies the number of crashes occurring at a location more than what would be expected. EEC is positive is more crashes are occurring than expected and negative is fewer crashes are occurring than expected. The following graphic shows a visual representation of the relationship between SPF predicted crashes, historic crashes, EB expected crashes, and EEC.



For the 2020 SHIFT cycle, EEC will be used as a standalone measure to replace the three measures that were used in conjunction to evaluate safety in the 2018 SHIFT cycle. EEC is a more statistically rigorous metric to evaluate safety because it follows current HSM guidelines, accounts for regression to the mean bias, and reduces length bias.

Instead of using the CD*L measure to distinguish between crash patterns on different roadway types, the safety team developed a new SPF for each roadway type for the 2020 SHIFT cycle. Individualized SPFs for each roadway type are used to calculate crash predictions, EB estimates, and EECs for projects for only roadways of that type. This method more accurately captures the differences in crash patterns on differing roadway types than a simple crash density average (CD*L). The Safety Team developed SPFs for the following roadway types: ramps, intersections, rural two-lanes, rural interstates/parkways, rural multilane divided highways, rural multilane undivided highways, urban two-lanes, urban interstates/parkways, urban multilane divided highways, and urban multilane undivided highways.

All 2020 SHIFT projects will be ranked based on the EEC of each project. The project with the highest EEC will receive the maximum number of safety points toward the overall SHIFT score based on the weight of the safety component. Each successive project will receive a lower score, with the amount of score reduction being linear and based on the total number of projects in the 2020 SHIFT cycle. In some instances, projects may have an EEC an order of magnitude higher than the next highest ranking project, even though their SHIFT safety scores will be close in magnitude due to the linear nature of the scoring process. The safety scores for these projects will come with a warning that their EEC is much greater than the next highest SHIFT project.